and will continue to be so until the many important principles which it involves, but which have not been introduced into the present discussion, have been further elucidated by new investigations and new thoughts.

X. "On the ultimate arrangement of the Biliary Ducts, and on some other points in the Anatomy of the Liver of Vertebrate Animals." By LIONEL S. BEALE, M.B., Professor of Physiology and Morbid Anatomy in King's College, London. Communicated by F. KIERNAN, Esq., F.R.S. Received June 14, 1855.

In his valuable communication to the Royal Society in 1833, Mr. Kiernan describes and figures anastomoses between branches of the biliary ducts in the left triangular ligament of the human liver. The same author considered that the interlobular ducts anastomosed with each other, and communicated with a lobular biliary plexus, although he had never succeeded in injecting this plexus to the extent shown in his figure, neither had he directly observed the anastomoses between interlobular ducts. It must be borne in mind that these observations were made before the liver-cells had been described.

Since the appearance of Mr. Kiernan's paper, various hypothetical views have been advanced by different observers, with reference to the arrangement of the minute biliary ducts and the relation which the liver-cells bear to them. These points, however, have not yet been decided by actual observation.

Müller considered that the ducts terminated in blind extremities. Weber showed that the right and left hepatic ducts anastomosed by the intervention of branches in the transverse fissure of the liver, which he described under the name of Vasa aberrantia.

Krukenberg, Schröder Van der Kolk, Retzius, Theile, Backer, Leidy and others have adopted the view that the liver-cells lie within a network of basement membrane. On the other hand, Handfield Jones and Kölliker describe the liver-cells as forming a solid net-

work, against the marginal cells of which Kölliker believes the extremities of the ducts impinge, while Handfield Jones holds that the ducts terminate by blind extremities.

Henle, Gerlach, Hyrtl and Natalis Guillot look upon the finest gall ducts as communicating with intercellular passages.

Dr. Handfield Jones looks upon the small cells in the extremities of the ducts as the chief agents in the formation of bile, and to the liver-cells he assigns an office totally distinct from this. Busk and Huxley concur in this view, which would place the liver in the category of vascular glands, spleen, suprarenal capsules, &c.

The observations of the author have been made upon the livers of several different animals examined under various circumstances. The results of the examination of injected preparations precisely accord with the observations made upon uninjected specimens some months before. The points which he hopes to establish are as follows:—

1. That the hepatic cells lie within an exceedingly delicate tubular network of basement membrane.

2. That the smallest biliary ducts are directly continuous with this network.

3. That at the point where the excretory duct joins the tubes which contain the secreting cells, it is very much constricted, being many times narrower than the tube into which it becomes dilated.

Lobules.—With reference to the nature of the lobules of the liver, the author offers some remarks. The only liver in which he has been able to detect distinct lobules, consisting of perfectly circumscribed portions of hepatic structure and separated from each other by fibrous tissue, is that of the pig. In this liver each lobule has a distinct fibrous capsule of its own, and is separated from its neighbours by the branches of the vessels and duct for their supply.

The lobules of the liver of other animals are not thus separated from each other, but the capillary network and the cell-containing network of one lobule are respectively connected with those of the adjacent lobules at certain points between the fissures in which the vessels and duct lie. In these livers there is not a trace of fibrous tissue between the lobules.

The exceptional liver of the pig, with its distinct lobules, seems to bear in structural peculiarity the same relation to the livers of other animals, as the much-divided kidney of the porpoise bears to the more solid organ of most mammalian animals.

In a *physiological* sense the livers of all vertebrate animals may be said to be composed of lobules; but in a strictly *anatomical* sense this term can only be used with reference to the liver of the pig, and, according to Müller, that of the polar bear. The vessels and duct, at their entrance into the liver, are invested with much areolar tissue, which is continued for a considerable distance along the portal canals; but it gradually ceases as the vessels become smaller, and, with the exception of the liver of the pig above referred to, the lobules are not separated from each other by any areolar tissue, or by any fibrous tissue whatever, neither is any prolonged into their substance. Hence the investment of areolar tissue round the vessels in the portal canals of the liver seems to present no peculiar characters in its distribution. It must be borne in mind, that in the examination of uninjected specimens the small vessels and ducts are liable to be much stretched and torn in manipulation, and, in consequence, a striated appearance is produced which closely resembles fibrous tissue.

Method of preparing specimens.—In order to demonstrate the arrangement of the ducts described by the author, it is absolutely necessary to harden the liver previously. This hardening may be effected by soaking a portion of the liver for some time in strong syrup, or in alcohol, and afterwards rendering the section transparent by soda. The mixture of alcohol and acetic acid recommended by Mr. L. Clarke in his investigations upon the spinal cord, has also been employed, as well as many other solutions which are not described. The fluid to which the author gives the preference is alcohol, to which a few drops of solution of soda have been added.

Method of injecting the biliary ducts.—The following is the method by which, after numerous trials, the author succeeded in effecting this object. Lukewarm water is injected into the portal vein. After a time, when the liver has become fully distended, much bloody water will escape from the hepatic vein, but at the same time it will be remarked that bile escapes from the duct. This

bile gradually becomes thinner, and at last nearly pure water flows from the duct, showing that the bile has been washed out. The liver is now placed in soft cloths to soak up the water, and after some hours it will be found to have diminished much in volume, and to have a clayey consistence. The ducts are now empty, and may be injected with a carefully prepared prussian-blue injection, to which a little alcohol has been previously added. The mixture is to be well stirred, and after having been carefully strained, it is slowly and cautiously injected into the duct. Plain clear size is next thrown into the portal vein, until the liver has become fully distended with it in every part. Lastly, a little plain size is injected into the duct, the vessels carefully tied, and the liver placed in cold water until the size has set, when very thin sections can be readily obtained with the aid of a sharp knife. The author has tried many other plans of injection, but the above has afforded the most satisfactory results. On one occasion a human liver was successfully injected with four different colours; the portal vein with flake-white, the artery with vermilion, the duct with prussian blue, and the hepatic vein with lake.

Evidence of the existence of a tubular basement membrane in which the liver-cells are contained.

Not unfrequently liver-cells are set free with shreds of delicate membrane attached to them, and this can sometimes be seen to be prolonged either way in the form of a narrow tube.

In certain specimens which have been exposed for some time to the action of dilute soda, the walls of the cells appear to be dissolved and the tubes are seen to be occupied with a highly refractive mass, and their outline is rendered very distinct.

When portions of the cell-containing network are placed in strong syrup or glycerine, exosmose of the water occurs, the diameter of the tubes is much diminished, and their outline becomes distinct, but uneven, in consequence of the shrunken state of the tubes of the network.

At the edge of a very thin section of liver stretching between two capillary vessels, a very thin membrane, recognizable only by the granular matter adhering to it, can sometimes be seen.

The tubes of the network can be distended to a great extent by

injection, so that the walls of contiguous tubes meet, while the capillary vessel between them becomes so compressed as not to be recognizable.

The injection often forms a sharp line towards the capillary vessels on either side of the tube in which the cells lie, and gradually shades off towards the centre of the tube.

The cells which escape into the surrounding fluid from injected specimens often have portions of injection adhering to them.

If a section be made at right angles to the intralobular vein, the cells are seen to form lines radiating from the centre towards the circumference of the lobule, as authors have before described. These lines of cells are really tubes of basement membrane, communicating with each other at intervals by narrow branches. In injected specimens the walls of the tube can be demonstrated, and are seen to be distinct from the capillary vessels.

In the fœtus, the cells are seen to be separated from the cavity of the vessels by two lines separated by a clear space. One of these lines is caused by the outline of the tube containing the cells, the other is that of the capillary wall.

The author supposes that, originally, the liver is composed of a double network of tubes (cell-containing network and capillary network), the walls of which in most situations become incorporated, so that the secreting cells are only separated from the blood by one thin layer of basement membrane, which is very permeable to water in both directions, but the greatest force which can be applied without causing rupture is incapable of forcing bile through it.

Of the contents of the tubular network of basement membrane, and of the arrangement of the cells within it.

Within the tubular network lie the hepatic cells, with a certain quantity of granular matter and cell débris, and, in some instances, free oil-globules and granules of colouring matter. The cells are not arranged with any order or regularity. Some observers have endeavoured to show that the hepatic cells are arranged in a definite manner. Professor Lereboullet, one of the latest writers on this subject (1853), describes the cells as forming double rows. The two rows of cells may be separated by injection, and he gives two diagrams to illustrate their arrangement. The author has never

seen anything like this in any liver which has been examined by him. In Mammalia, according to his observation, the cells are for the most part arranged in single rows (human subject, pig, dog, cat, rabbit, horse, seal, Guinea-pig and others), but in some situations two cells lie transversely across the tube, and they may be forced into this position by injection. The cells do not completely fill the tubes, and are not always placed quite close together, being surrounded with granular matter. Injection passes sometimes on one side of the tube, and sometimes upon the other; often it entirely surrounds a cell. In the human fœtus and in the fœtal calf there are two or three rows of cells within the tubes, and this is also the case in the livers of most adult reptiles and fishes which have fallen under the author's observation, and in many parts of the network of the bird's liver.

Of the Ducts of the Liver.

The duct, like the artery, lies close to the portal vein; usually this vessel is accompanied by one branch of the artery and duct, but not unfrequently there are two or three branches of these vessels with the vein.

Anastomosis of the ducts near the trunk from which they come off.—The author observes that the anastomoses between the larger ducts and between the larger branches of the interlobular ducts are pretty numerous in the human liver, but these communications take place only near the origin of the trunks by means of intermediate branches. Different interlobular ducts do not anastomose with each other, but the branches resulting from the division of a small trunk are often connected together.

In some animals these communications are so numerous, that a complete network is formed at the portal aspect of the lobule, or around a small branch of the portal vein.

Not only are the right and left hepatic ducts connected together by intermediate branches in the transverse fissure of the liver, as E. H. Weber long ago demonstrated, but the branches coming off from these communicate with each other as well as with the trunks from which they come off. These branches are very numerous, and form an intimate network of irregular branched ducts. Similar communications occur between the branches in the portal canals,

but they are not so numerous. This arrangement occurs to a less extent in the dog and in the calf, but it is not present in all animals. The author has not been able to demonstrate it in the pig, seal, rabbit, horse, cat and monkey, although he is not prepared to say that, absolutely, no communications take place between the ducts near their origin, in these animals.

Of the glands of the ducts.—The so-called glands are small cavities of a rounded or oval form, or more or less branched, which communicate with the cavity of the duct by a very constricted neck. The simple glands are for the most part situated in the coats of the ducts, so that, when injected, they scarcely project beyond the external surface. These cavities or glands are most easily demonstrated in the pig.

When a small duct from the human liver is laid open, two lines of orifices are seen opening upon the internal surface, as Kiernan described. The great majority of these, however, are not the openings of glands, but almost all of them are the orifices of branches of the duct which communicate with each other in its coats, or just at the point where they leave it. Very few of them are the openings of cæcal cavities, which are very rare in the smaller ducts of the human subject.

Vasa aberrantia.—There are many curious branches of communication between the ducts in the transverse fissure of the liver, which have been well named " vasa aberrantia " by Weber. Theile looks upon all these ducts as anastomosing mucus-glands. The author has seen these ducts in the portal canals, down to those not more than one-eighth of an inch in diameter. They present the same characters as the branches in the transverse fissure, but are not so numerous. The coats of the vasa aberrantia are thinner than those of the ordinary ducts, and, like them, are lined with epithelium, principally of a subcolumnar form. These branches are always surrounded by areolar tissue, in which lymphatics are very numerous. The arrangement of the vessels about the vasa aberrantia is peculiar. The arteries and veins form a network, and each small branch of the artery lies between two branches of the vein, which communicate with each other at frequent intervals by numerous transverse branches, some of which pass over and some under the artery. The author observes that this beautiful arrangement of the vessels

occurs in the gall-bladder, in the transverse fissure, and in the portal canals. This disposition of the veins has the effect of ensuring free circulation through them under different conditions, as when they are stretched or compressed.

The vasa aberrantia in the transverse fissure of the adult human liver are nearer to the branch of the portal vein than to the hepatic substance, and can be readily removed without any of the latter. A few small straight branches are sometimes observed to come off from the vasa aberrantia and to enter the hepatic substance. In the fœtus, on the other hand, the vasa aberrantia are fewer in number, their course generally is more direct, they lie so close to the hepatic tissue that they cannot be removed unless a portion of the latter is taken away with them, and very many of the branches can be traced into the hepatic substance.

The author regards the vasa aberrantia in the adult liver in the light of altered secreting tubes, and believes that at one time they formed a part of the secreting structure of the liver. At the termination of intrauterine life the portal vein increases in size, and the pressure thus produced may account for the gradual wasting and partial disappearance of the hepatic substance closely surrounding it. In the very thin edge of a horse's liver, which consisted principally of areolar tissue, the gradual alteration of the ducts and ultimate complete disappearance of the secreting cells was traced. Upon the surface of the portal vein in the rabbit's liver the transitional stages between the compact lobule of secreting structure and the branches of the vasa aberrantia have been well seen.

Function of the glands and vasa aberrantia.—It has always been considered that the office of the ducts was to secrete the mucus of the bile, and a similar function was assigned to the vasa aberrantia by Theile. It seems to the author that a cavity communicating with a tube by a neck of less than $\frac{1}{5000}$th of an inch in diameter, cannot be well adapted for pouring out a viscid, tenacious mucus. If these cavities contained mucus, the injection would not enter them so readily as it does, nor is it easy to conceive how the mucus poured out by these little glands would become thoroughly mixed with the bile as it passes along the ducts. Again, the bile of the pig, in which animal these glands are very abundant, does not contain more mucus than the bile of the rabbit, in which they are few

in number and only found on the largest branches of the duct. The vasa aberrantia do not possess any characters which, in the opinion of the author, justify the inference of their being mucus-glands. He regards the little cavities in the coats of the ducts (glands of the ducts) and the vasa aberrantia as reservoirs for containing bile, whilst it becomes inspissated and undergoes other changes. By these cavities in the ducts with thick walls, the bile is brought into close relation with the vessels which ramify so abundantly upon the external surface of the ducts.

Of the finest branches of the duct, and of their connexion with the cell-containing network.

Mammalia.—In well-injected preparations the smallest branches of the duct can be readily traced up to the secreting cells of the lobules. In most Mammalia, but not in the pig, a few of the finest branches of the duct can be followed for some distance beneath the surface of the lobule. These branches appear to lie amongst the secreting cells, but are not connected with them. They become continuous with tubes of the cell-containing network at a deeper part, while those secreting tubes nearer the surface of the lobule are connected with branches of the duct which do not penetrate.

In many animals, particularly in the rabbit, and to a less extent in man and in the dog, the smallest branches of the duct are connected together so as to form a network, which is continuous with that in which the secreting cells lie.

In the pig, the small ducts are, as it were, applied to the surface of the lobule; from these smaller branches come off, which penetrate the lobule and are immediately connected with an intimate network, which lies partly in the capsule of the lobule itself. This network is continuous with, and may be looked upon as the most superficial portion of, the cell-containing network. In a perfectly normal state it contains only oil-globules and granular matter; but when the liver is fatty, it is found to contain liver-cells loaded with oil. From such a liver the author has a very beautiful preparation, in which the continuity of the very narrow duct with the wide tubes of the network, distended with large cells containing oil, can be well seen. The duct and the tubes in which the secreting cells lie, both contain a little injection.

The author has succeeded in demonstrating the communication between the ducts and cell-containing network in several mammalian animals, as well as in the human subject, by injecting the ducts in the manner described. Of these, the seal, hedgehog, rabbit and Guinea-pig have afforded the best specimens.

In *Birds*, the continuity in injected specimens has been traced in the common fowl and in the turkey. The quantity of epithelium in the ducts of birds forms a great obstacle to the passage of the injection, and from their extreme tenuity, the capillaries do not bear the preliminary injection of much water.

Reptiles.—The author has seen the continuity between the ducts and cell-containing network, in an uninjected preparation of the newt's liver, and in an injected liver of the adder.

Fishes.—In consequence of the very fatty nature of the liver of fishes, it was found to be very difficult to harden it sufficiently to cut thin sections. The frequent presence of entozoa and their ova, renders it difficult to inject the ducts. The author succeeded in injecting the ducts and part of the cell-containing network in the sturgeon and in the Lophius, and in one instance, those of the very fatty liver of the cod. The continuity was also traced in an uninjected liver of the common flounder. The injection often passes a certain distance into the finer ducts of fishes, but cannot be forced into the cell-containing network. In this way the appearance of blind terminations to the ducts is produced, as the continuity of the tube cannot be traced beyond the point at which the injection stops.

The continuity of the finest ducts with the cell-containing network has been demonstrated in all classes of Vertebrata, both in injected and also in uninjected specimens. In all the livers of vertebrate animals which have been examined, the duct becomes much narrowed at the point where it joins the network in which the cells lie. The arrangement of the small ducts varies somewhat in different animals. Sometimes a network of minute ducts is formed, which is continuous with that in which the cells lie. In other instances the communications between these terminal ducts are very few in number, or are altogether absent. Upon the latter point the author does not express himself positively, as he is sure that in the most perfect injection which he has been able to make, the whole of

the numerous branches of the minute ducts have not been injected; and from observations upon these specimens alone, he feels that only a very imperfect idea can be formed of their number or of their arrangement.

Diameter of the ducts.—A table is given, showing the thickness of the coats of the ducts in different parts of their course. The walls of the smallest ducts are composed entirely of basement membrane, and are often not more than the $\frac{1}{5000}$th of an inch in diameter in the uninjected state. In the pig, the diameter of the smallest ducts containing injection was about the $\frac{1}{3000}$th of an inch; in the human subject, about the $\frac{1}{2500}$th; in the seal, $\frac{1}{3000}$th; and in some fishes not more than the $\frac{1}{5000}$th of an inch. It may be remarked, that this narrowing of the excretory duct, just before it becomes continuous with the secreting portion of the organ, is seen in the kidney and in other glands.

Epithelium of the small ducts.—The epithelium lining the smallest ducts presents very similar characters in different animals. The small cells are for the most part oval or circular in form; sometimes they are angular, which probably results from pressure or stretching of the ducts in the preparation of the specimen; sometimes the smallest ducts appear to be entirely filled with epithelium; in other instances the cells are very sparingly and irregularly scattered over the interior of the tube, while frequently no cells whatever can be distinguished.

The author believes that, in a perfectly normal state, the minute ducts are lined by a single layer of delicate epithelial cells.

This ductal epithelium does not pass gradually into the secreting epithelium, but ceases at the point where the latter begins. Hepatic cells are sometimes seen in tubes lined with this ductal epithelium, but probably their presence is the result of accident. In these cases the ducts are of course much stretched or dilated *.

With reference to the relation of the ductal epithelium to the secreting cells of the liver, the author observes that a very similar arrangement occurs in the gastric glands. The secreting epithelium is alone found in the lower part of the gland (stomach tube), while the ductal portion of the gland is lined with columnar epithelium.

* Mr. Wharton Jones has also seen hepatic cells in the small ducts.—*Phil. Trans.*

The secreting cells appear to occupy the entire cavity of the tube, and are not arranged in any order; so that the secretion, having escaped from the cells, must pass off towards the duct by the slight interstices between them. A similar disposition of the secreting epithelial cells occurs, but in a less remarkable degree, in some other glands; as the pancreas, lacteal, sebaceous, and sweat glands.

The conclusions to which the author has arrived may be summed up as follows:—

1. That the liver of vertebrate animals essentially consists of two solid tubular networks mutually adapted to each other. One of these networks contains the liver-cells, and the other the blood.

2. The cell-containing network is continuous with the ducts. The small delicate epithelial cells lining the latter channels contrast remarkably with the large secreting cells, which are not arranged in any definite manner within the tubes of the network.

3. The duct is many times narrower than the tubular network at the point where it becomes continuous with it.

4. Injection passes sometimes on one, and sometimes on the other side of the tube, or between the cells, when two or more lie across the tube. Often, a cell becomes completely surrounded with injection. As injection can thus be made to pass readily *from* the ducts into the network and around the cells, it follows that there can be no obstacle to the passage of the bile along the same channels in the opposite (its natural) direction.

5. In some animals, the most minute ducts are directly connected with the tubes of the cell-containing network; of these branches, some pass amongst the most superficial meshes to join the network at a deeper part. In other animals the finest ducts first form a network which is continuous with that containing the liver-cells.

6. The interlobular ducts do not anastomose, but the branches coming off from the trunk are often connected with each other, as well as with the parent trunk, near their origin from it.

7. The walls of the smallest ducts are composed of basement membrane only. The thick complex coat of the larger ducts contains within it small cavities (the so-called glands of the ducts), by means of which the bile in these ducts would be brought into close proximity with the arteries, veins and lymphatics, which are very abundant wherever the ducts ramify.

8. The office of the vasa aberrantia, which are so numerous in the transverse fissure of the human liver and in the larger portal canals, appears to be similar to that of the cavities in the walls of the ducts. It is worthy of remark, that the network of vessels ramifying so abundantly in the coats of the gall-bladder, in the transverse fissure, and in the larger portal canals, are arranged in a similar manner, each branch of artery being accompanied by two branches of the vein.

9. The liver is therefore a true gland, consisting of a formative portion and a system of excretory ducts directly continuous with it. The secreting cells lie within a delicate tubular network of basement membrane, through the thin walls of which they draw from the blood the materials of their secretion.

XI. "Experimental Researches on the Movement of Atmospheric Air in Tubes." By W. D. CHOWNE, M.D. Communicated by JOHN BISHOP, Esq., F.R.S. Received June 14, 1855.

In the year 1847, the author of this paper made numerous experiments for the purpose of ascertaining what are the conditions under which atmospheric air is placed with regard to motion or rest, when within a vertical tube having one extremity communicating within the interior of a building, and the other in the open atmosphere.

The paper now submitted to the Royal Society contains the results of investigations undertaken in the year 1853 and continued to the present time, to ascertain whether the ordinary state of atmospheric air contained in a vertical cylindrical tube, open at both ends, and placed in the still atmosphere of a closed room, is one of rest or of motion; and if of motion, to investigate the influences of certain changes in the condition of the atmosphere which either produce, promote, retard, or arrest the movement.

He demonstrates, by a series of experiments, that when a tube, open at both ends, is placed in a vertical position, every precaution being taken to exclude all extraneous causes of movement in the surrounding atmosphere, an upward current of air is almost imme-